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(54) Abstract Title
Multilayered optoelectronic circuit board with transparent layers

(57) Optoelectronic, multilayer printed circuit board having at least one outer attachment/placement layer (7), which comprises on the outer side of the layer structure an electric conductor track (9), and having optical signal transmission paths which are structured as integrated multimode waveguides in a system having additional, optically transparent layers (1, 2, 4). In order to produce cost-effectively: (a) optical multimode connection lines with passive structures, (b) coupling sites for optical fibres and for optoelectronic components for the purpose of transmitting and receiving optical signals, and (c) conventional electric signal connections on a common carrier, the transparent layers (1, 2, 4) are located inside the layer structure and substantially conventional methods are employed for the purpose of structuring these layers. A layer (6) for thermomechanical adaption can also be included which is positioned between the optically transparent layer system and the outer attachment/placement layer (7). A micro-prism (13) is also included in the method where the prism (13) is attached to an optoelectronic component (17) and both are subsequently adjustable.

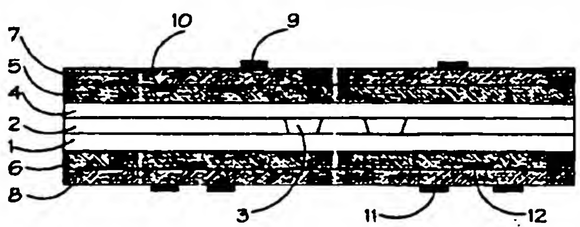

FIG.1.

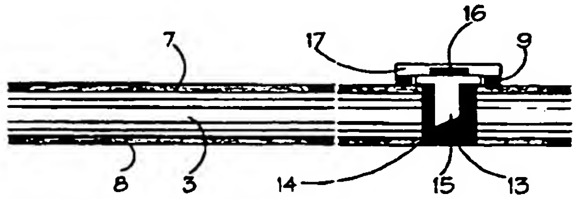

FIG.2.

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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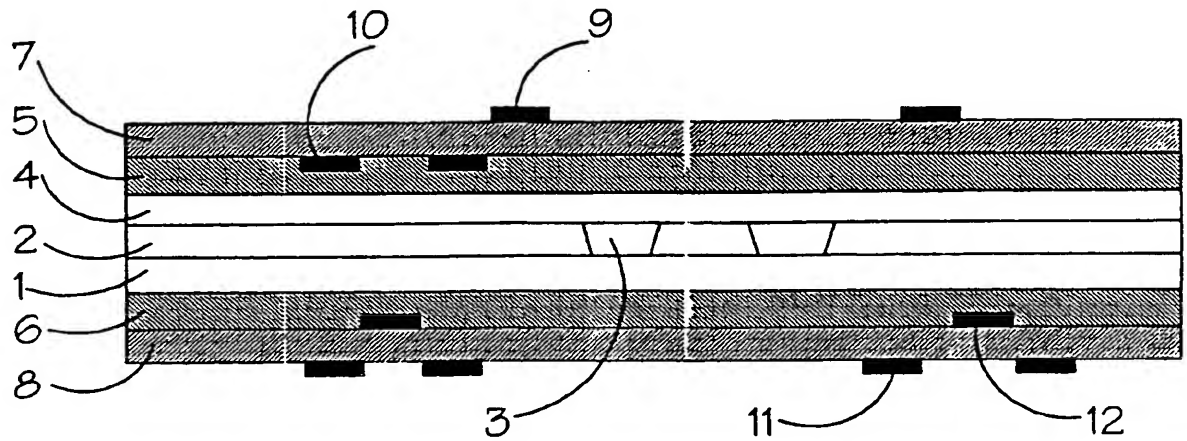

FIG.1.

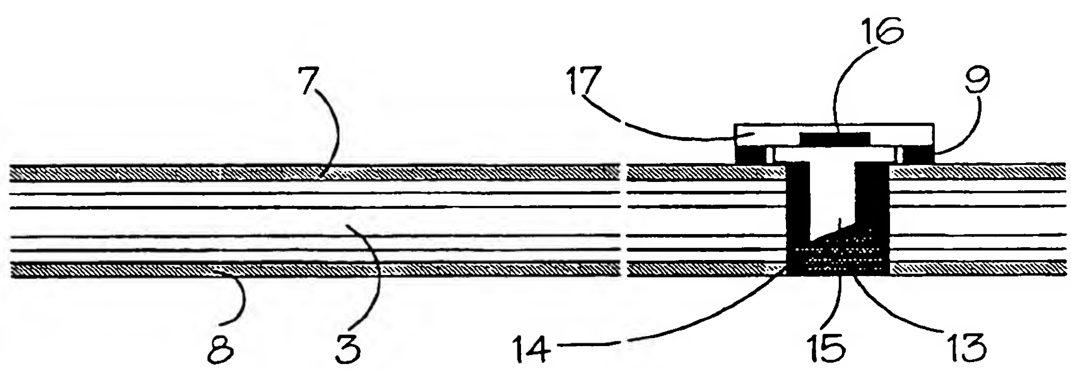

FIG.2.

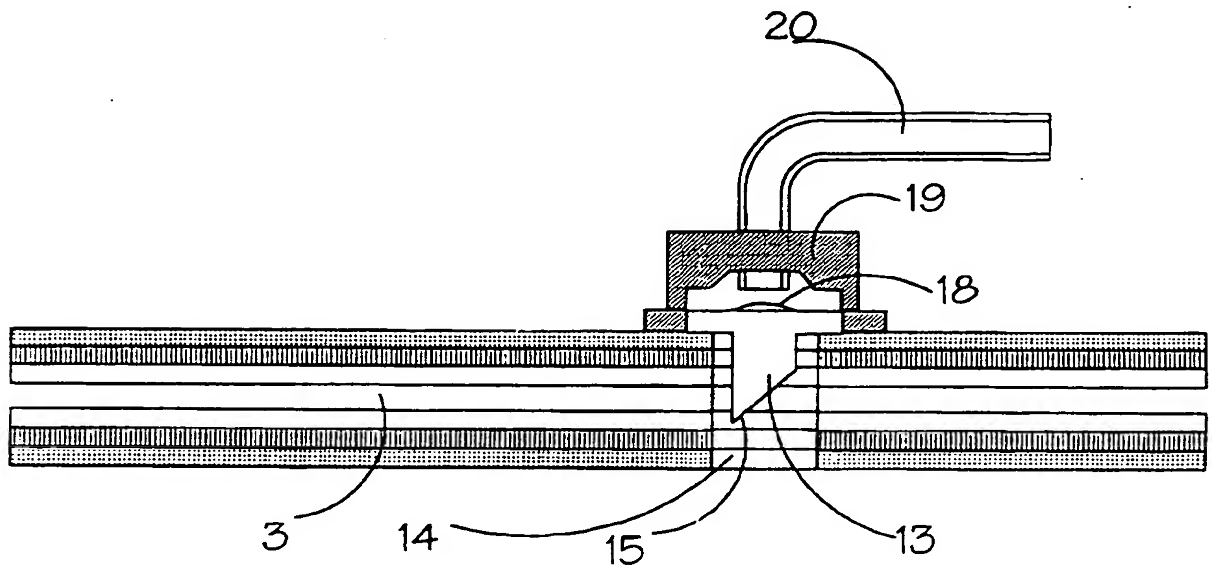

FIG.3.

DESCRIPTION

PRINTED CIRCUIT BOARD AND METHOD OF PRODUCING SAME

The invention relates to printed current boards and to methods of producing same and is concerned in particular with optoelectronic printed circuit boards of the type which form a multilayer package, and the manufacture of such devices. For devices relating to information and communication technology, there is an ever increasing demand for signal transmission paths which with low interference susceptibility and high data rates enable data to be transmitted in a reliable, error-proof and at the same time cost-effective manner. This development can be attributed essentially to the dramatic increase in the efficiency of modern microelectronics for computer systems and the peripheral equipment thereof. In the field of mobile communications systems - for example for motor vehicles - significant requirements such as weight reduction, ease of assembly and servicing are also factors. This development is enhanced by the introduction of networked systems for information and communication.

Whereas optical signal transmission has been introduced for greater distances, its broad use in the area of application of smaller, where appropriate, mobile LANs (local area networks) or also for the signal transmission on the subassembly level is prevented by reason of the additional costs of optical transmission technology which at the present time are still to be applied. However, owing to the relatively short distances to be

covered (maximum of approximately 500 m) it is possible to utilize optical multimode waveguide systems for use in the shortwave spectrum (ca. 630-850 nm), since in this case it is possible to reduce costs owing to the reduced geometric tolerances and the less stringent demands upon low transmission loss of the materials. Cost-effective synthetic material fibres already exist which comprise sufficiently low transmission loss and suitable optoelectronic transmitter and receiver components are already commercially available or will be introduced to the market shortly. In the field of consumer electronics various bus systems for broad-band signal transmission are currently being standardized, wherein particular significance is attached to the real-time capability for high-quality transmission of audio-visual information. In this instance, the optical data transmission via multimode fibres plays a crucial part, the significance of which will continue to increase in the future.

If different electronic devices or also subassemblies within a device are to be operated in a system which is networked, for example, by means of synthetic material fibres, then there is also a requirement for cost-effective optical connection technology. Passive optical components are required for the purpose of constructing in flexible manner networks which have different topologies. Optical beam formation can be employed in order to adapt the beam cross-sections, which are predetermined by the optoelectronic components, to suit those of the multimode fibres, so that it is possible to keep power losses to a minimum.

Since electronic devices are mostly constructed on the basis of printed circuit boards, there is consequently the need to produce optical signal transmission paths between individual subassemblies of a printed circuit board or between various printed circuit boards, for the purpose of producing passive optical components such as power dividers, power combiners or star couplers and cost-effective methods of coupling optical fibres. The structure and method of producing hybrid electric/optical printed circuit boards will be described hereinunder and render it possible to produce cost-effectively

• optical multimode connection lines with passive structures,

• coupling sites for optical fibres and for optoelectronic components for the purpose of transmitting and receiving optical signals,

• conventional electric signal connections on a common carrier.

In modern printed circuit board technology, complex, multilayer, flexible or rigid layer systems are used as carriers which are suitable for SMD-placement procedures. By selecting different base materials, it is possible to produce electric signal connections having a defined impedance and controlled signal running times. Typical, well-mastered structure dimensions (printed circuit board widths and spacing therebetween) are approximately 40μm. Epoxy resin-glass woven material (e.g. FR-4) is frequently used as the printed circuit board substrate material. Multilayer printed circuit boards have been constructed from the most varied material combinations, for example, Teflon and FR-4 or Teflon and PMMI. Also, it is essentially known to use additional layers for

the purpose of compensating for different thermal extension coefficients.

Optical waveguide structures for single-mode and multimode operation have been produced using many different methods in various material systems, also including synthetic material sheets. Amongst the numerous production methods, replicative methods are particularly cost-effective, if the required geometric structure accuracies are in the range of a few micrometers, i.e. if multimode structures are to be used.

One possibility of waveguide production is to structure a core layer, which is applied to a substrate, by a stamping process in such a manner as to produce a pattern of recesses corresponding to the desired waveguide arrangement, and these recesses are to be filled subsequently with a further optically transparent material. This second material must have a higher refractive index than the substrate material, so that light can be guided in the waveguide. An additional cover layer having a lower refractive index than the waveguide core is required, so that the adjacent, non-transparent layers in the printed circuit board structure do not disrupt the light propagation in the optical layer system. One example of a replicative method of producing optical multimode waveguide structures is provided in the European Patent document EP 0 480 618 B1. However, the integration of such structures in printed circuit boards is not mentioned or covered in the claims.

A further possibility of producing waveguides employs photolithographic methods. Conventionally, a transparent substrate layer is initially coated with a film consisting of light-sensitive material. In this material, it is possible to change chemical bonds by virtue of exposure to shortwave light such that either the exposed or unexposed portion of the material becomes soluble with respect to a solvent and can therefore be removed in a further operational step. For example, it is possible after the exposure to remove the material outside the waveguide cores provided, whereby the waveguide cores remain as a rib structure on the substrate layer. This structure is finally supplemented by a transparent cover layer, in order then to obtain a planar surface for the subsequent laminating steps. In order to ensure that it is possible to guide the wave optically, the refractive index of the structured waveguide cores must be greater than the indices of the adjacent layers.

The optical coupling of surface-mounted, optoelectronic components via reflective facets on waveguide structures which have been produced in additional polymeric layers on the surface of printed circuit boards, has been demonstrated [Thomsen, J.E., H. Levesque, E. Savov, F. Horwitz, B.L. Booth, J.E. Marchegiano, "Optical waveguide circuit board with a surface-mounted optical receiver array", Optical Engineering, vol. 33, no. 3, 939 (1994)].

In accordance with one aspect of the present invention, there is provided an

optoelectronic printed circuit board which forms a multilayer layer package, having at least one outer attachment layer which comprises at least one electric conductor track on the outer side of the multilayer layer package, and having at least one optical signal transmission path, which is structured as an integrated multimode waveguide in a layer system comprising additional, optically transparent layers located inside the layer package.

By this means, the layer system of conventional printed circuit boards can be extended by an internal system of at least one transparent layer, in which an optical waveguide structure is defined, for example, using deformation processes or by means of a photolithographic procedure. After laminating the entire layer stack, a compact structure similar to conventional printed circuit boards is produced and has additional optical structures located inside.

The production of optical signal connections in one or several additional transparent internal layers of a printed circuit board using substantially conventional techniques in the printed circuit board industry goes beyond the prior art. The same applies to the optical coupling of optoelectronic components to internal layers of this type via beam-deflecting facets.

It is possible to couple optoelectronic components to internal optical multimode

waveguides by virtue of reflective micro-prisms which during assembly of the printed circuit board are placed together with the components, which are to be coupled, in such a manner that their reflective surfaces lie in orifices (for example produced by bores) which are provided for this purpose.

Advantageous embodiments are defined in the dependent claims, the features of which can also be combined where appropriate.

It is preferable to apply the invention to multilayer printed circuit boards, whose layer structure contains a system of optically transparent materials having optical multimode strip waveguides.

One embodiment of the invention is explained in detail hereinunder by way of example only and is illustrated in the drawings, in which the following figures are illustrated in a schematic manner and not to scale, wherein:-

Figure 1 shows an illustration of the layer structure of a hybrid electric/optical printed circuit board;

Figure 2 shows an illustration of the coupling of an optoelectronic component to a

waveguide in an optical printed circuit board plane; and

Figure 3 shows the coupling of an optical multimode fibre to an optical waveguide inside an electro-optical printed circuit board.

Like parts in the different figures are designated substantially by like reference numerals.

The schematic sectional view in Figure 1 shows on a substrate layer 1 a core layer 2 with two waveguide cores 3 which are covered by a cover layer 4. These three layers 1, 2, 4 are located between two thermomechanical adaption layers 5, 6 which for their part are disposed between two electric placement layers 7, 8. These electric placement layers each support on both sides electric conductor tracks 9 to 12. The outer sides of the electric attachment layers 7, 8 having the conductor tracks 9, 11 each form attachment planes for the attachment procedure using electric and/or electro-optical components.

It is not essential to the invention whether only one, two, three or all four sides of the placement layers are provided with conductor tracks.

The integration of optical waveguide structures offers the advantage of producing

broadband and (with respect to emissions and imissions of electromagnetic radiation) interference-insensitive signal connections together with conventional electric interconnects on one common carrier. Cost benefits can be gained from using substantially conventional structuring technologies.

The advantage of an arrangement of the optical layers inside the printed circuit board is that the placement planes remain substantially unaffected and it is possible to continue to use existing electric circuit layouts. Furthermore, a symmetrical layer structure of the printed circuit board is achieved, which has favourable effects with respect to the thermomechanical stability and reliability. For example, during changes in temperature this would obviate any deflections which would otherwise occur by reason of different coefficients of extension in the case of an asymmetrical layer structure.

In order to produce electric/optical printed circuit boards, optical waveguide structures are initially structured in one or several layers of optically transparent material, for which reason it is possible to employ various methods according to prior art.

The system, which is prefabricated in this manner, consisting of a substrate (where appropriate on additional carrier material), waveguide cores and a cover layer is subsequently assembled with the conventional placement layers and additional layers for the thermomechanical adaption process to form a layer stack and then laminated.

Since the laminating process is performed at approximately 160 to 180°C, it is necessary to concentrate corresponding requirements on the heat resistance of the transparent materials used.

The use of conventional structuring technologies for the purpose of producing optical multimode waveguides is essential for producing in a cost-effective manner optical signal transmission paths in printed circuit boards. The structure variables of these waveguides (linear core dimensions of ca. 40μm and above) are well suited to currently conventional conductor track structural dimensions. The methods which can be employed include both photolithographic methods which utilize, for example, direct laser exposure, and also stamping methods which are already used in the field of non-transparent synthetic materials in the printed circuit board industry.

The geometry of an optical coupling site between an optoelectronic component, a reflective facet and a waveguide is illustrated in a schematic manner in Figure 2.

The layer structure is the same as in Figure 1. Figure 2 can be considered as a sectional view of Figure 1 along a waveguide core 3. From one side of the multilayer printed circuit board, said printed circuit board is penetrated as far as into the core layer by a micro-prism 13 which is disposed in an orifice (bore) which is filled with a index-matched adhesive 14. The micro-prism 13 comprises on one end a facet 15 which is

reflective (for example by virtue of metallization) and which forms an angle of 45° with the longitudinal axis of the waveguide core 3 and the bore axis. At the other end of the micro-prism there is located the active surface 16 of an optoelectronic component 17, i.e. an optoelectronic converter, be it a radiation source or a radiation detector such as a laser or alternatively a photo-detector. The optoelectronic component 17 is electrically contacted with conductor tracks 9 on the outer side of the electric placement layer 7.

In order to couple these types of optoelectronic components 17 (transmitter and receiver) which are mounted in a subsequent placement step it is therefore possible to provide orifices at the intended sites through the layer structure of the printed circuit board. These orifices must fully include the waveguide core in order to achieve the most efficient coupling arrangement possible. Prefabricated micro-prisms are bonded into these orifices in such a manner that light can be deflected from the waveguide plane at approximately 90° in the direction of the orifice axis. Preferably, metallized facet surfaces which are inclined at approximately 45° with respect to the waveguide axis are used for this purpose. After inserting the micro-prism, the remaining hollow space in the orifice, in particular of a bored hole is expediently filled with a transparent adhesive substance. The refractive index of this adhesive material can be selected in such a manner as to minimize optical reflections between the waveguide cores and the prism body. The influence of the bore peripheral surface with respect to its shape and roughness on the optical coupling efficiency is minimized in this manner. Furthermore,

hollow spaces which are filled with air are prevented which would otherwise cause difficulties in subsequent processing steps such as soldering procedures.

Micro-prisms can also initially be attached to the associated optoelectronic components (such as by adhesion), after which the component including the micro-prism is mounted on the printed circuit board and contacted. The process of filling the remaining hollow space with optically transparent adhesive can be performed both prior to and after the placement of the micro-prisms depending upon the requirements with respect to manufacturing technology.

Figure 3 shows in a schematic manner the coupling arrangement of an optical multimode fibre to an optical waveguide inside an electro-optical printed circuit board. On the site of the optoelectronic component (cf. Figure 2) there is located a fibre receiving arrangement 19 which mechanically fixes an optical fibre 20 and is positioned relative to a lens 18. The lens 18 is preferably produced by virtue of the fact that the micro-prism component is formed, for example, in the shape of a dome on its outer upper side. Therefore, the lens is preferably manufactured as a component of the micro-prism in a single operation (for example an injection-moulding process). The optical function of the lens is to transform an incoming, divergent light bundle into an outgoing, convergent light bundle, in order to obtain the best coupling efficiency possible between the integrated waveguide and the optical fibre. This applies both to the process of

coupling-in light from the fibre into the integrated waveguide and to the opposite direction. The fibre receiving arrangement 19 is attached, for example, by adhesion to the component placement side of the printed circuit board.

Alternatively, it is feasible to provide the fibre on its end with a reflective facet (45° inclined grinding and metallization) and to bond said fibre directly into the orifice, in order, therefore, to be able to omit the separate micro-prism. However, this procedure is encumbered with relatively costly fibre preparation, the problematic adjustment between the fibre and the integrated waveguide and the difficulties of then releasing this type of coupling as required.

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CLAIMS

1. An optoelectronic printed circuit board which forms a multilayer layer package, having at least one outer attachment layer which comprises at least one electric conductor track on the outer side of the layer package, and having at least one optical signal transmission path, which is structured as an integrated multimode waveguide in a layer system comprising additional, optically transparent layers located inside the layer package.

2. A printed circuit board according to claim 1, wherein two outer placement layers which flank the optically transparent layer system on both sides are provided with conductor tracks.

3. A printed circuit board according to claim 1 or 2, wherein between the optically transparent layer system and the outer placement layer there is provided a further layer for thermomechanical adaption.

4. A printed circuit board according to any one of the preceding claims, wherein in order to couple optically an optoelectronic component or an optical fibre to the inner optical multimode waveguide, a micro-prism is provided in an orifice of the printed circuit board, wherein a reflective facet of the micro-prism is located

in the plane of the optical waveguide core and the micro-prism is attached by means of a refractive index-matched adhesive such that a light bundle is deflected from the waveguide axis into the orifice axis or vice versa.

5. A printed circuit board according to claim 4, wherein the adhesive fills the gap between the micro-prism and the peripheral surface of the orifice in the region of the waveguide core.

6. A method of producing an optoelectronic printed circuit board which forms a multilayer layer package, having at least one outer placement layer, which comprises on the outer side of the layer package at least one electric conductor track, and having an optical signal transmission path which is structured as an integrated multimode waveguide in a layer system comprising of additional, optically transparent layers, wherein these layers are located inside the layer package and wherein in order to couple optically an optoelectronic component or an optical fibre to the inner optical multimode waveguide, a micro- prism is provided in an orifice of the printed circuit board, wherein a reflective facet of the micro-prism is located in the plane of the optical waveguide core and the micro-prism is attached by means of a refractive index-matched adhesive such that a light bundle is deflected from the waveguide axis into the orifice axis or vice versa, wherein initially the micro-prism is attached in the orifice and

subsequently the optoelectronic component is adjusted and mounted relative to the micro-prism.

7. A method of producing an optoelectronic printed circuit board which forms a multilayer layer package, having at least one outer placement layer, which comprises on the outer side of the layer package at least one electric conductor track, and having an optical signal transmission path which is structured as an integrated multimode waveguide in a layer system consisting of additional, optically transparent layers, wherein these layers are located inside the layer package and wherein in order to couple optically an optoelectronic component or an optical fibre to the inner optical multimode waveguide, a micro- prism is provided in an orifice of the printed circuit board, wherein a reflective facet of the micro-prism is located in the plane of the optical waveguide core and the micro-prism is attached by means of a refractive index-matched adhesive such that a light bundle is deflected from the waveguide axis into the orifice axis or vice versa, wherein initially the micro-prism is attached to the optoelectronic component and subsequently the two are adjusted and attached in the orifice.

8. An optoelectronic printed circuit board substantially as hereinbefore described with reference to and as illustrated in the accompanying drawings.

9. A method of producing an optoelectronic printed circuit board, substantially as herein described with reference to the accompanying drawings.

The Patent Office

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13.

Application No: GB 9918909.4
Claims searched: 1 - 9

Examiner: Andrew P Jenner
Date of search: 25 October 1999

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.Q): G2J: JGEAE, JGDB

Int Cl (Ed.6): G02B

Other: World Patents Index, Epodoc, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	EP 0272027 A2	AMERICAN TELEPHONE & TELEGRAPH CO. - whole document relevant, esp. col 6 line 19 - col 7 line 3	1 - 6
X	US 5757989 A	FUJITSU LTD. - see figures 17(all) and figure 28.	1 - 3

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.